Real-Time Fatigue Monitoring System with Facial Expressions: A Review

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Abstract. The Adjusters International disaster response report indicated that fatigue-related accidents are common in many industries; thus, they relate to the emergency response and require reliable monitoring solutions. In the proposed system, facial features related to the eye are going to be continuously tracked using the dlib library: head position, closure, and mouth movements. Therefore, the proposed system would sound a local alarm after 10 seconds before detecting the eyes closed. When a repeat event is detected, it can also send notification escalations to family members via the Twilio API. It looks out for prolonged signals of sleepiness, and any unusual head movement, for a complete fatigue assessment. The system is powered by real-time processing that allows it to take immediate action when fatigue has been detected, and location data integrations. Enhances response to intervention. The system produces detailed session reports that facilitate long-term analysis of fatigue patterns. The results appear to be very high in recognizing various degrees of fatigue.

Keywords: Fatigue detection, facial analysis, computer vision, real-time monitoring, drowsiness alert

1 Introduction

Fatigue is ranked as the number one killer on our roads; however, drowsy driving alone is estimated to cause 100000 accidents, 1500 fatalities, and 71000 injuries every year in the United States of America according to NHTSA. Stress sources, lack of sleep, shift work, disrupted biorhythms, and continuous mental exertion are widely regarded as major causes of driver fatigue. Fatigue monitoring technologies incorporated in IoT smart wearable devices and technologies, which include facial recognition, as well as heart rate and SpO2 detection [1]. which aid greatly in the prevention of accident occurrence. Fatigue and drowsiness are critical factors in many road accidents, as highlighted in studies focusing on real-time monitoring systems to reduce such risks [2]. In similar studies, hybrid models outperformed traditional methods, achieving an accuracy of 82.73% on the SEED-VIG dataset [3]. Similarly, EEG-based systems employing deep neural networks, such as the Inception-Res Net architecture, have shown great success in fatigue detection through brain signal analysis [4]. These systems are required in safety-related operations like driving, and in any other task that is likely to cause fatigue.

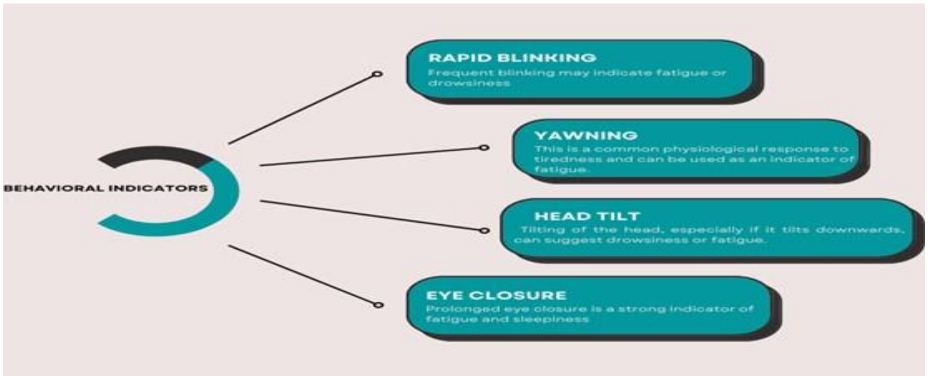

Fig. 1. Behavioral indicators for fatigue detection.

A fatigue detection system is depicted in the above picture. It begins with the major box labeled 'Fatigue Detection' and is followed by 'Person's behavior features-based.' This then leads into two branches, with four indicators of fatigue-Fast Blinking, Yawning, Head Tilt, and Eye Closure-following. It displays the process flow and the behavioral characteristics used to identify weariness in a fairly tidy and straightforward manner.

2 Preliminaries

2.1 Op enCV

Given its wide range of modules and efficient memory management, OpenCV is most likely unmatched in the world of computer vision. Its architecture allows images and videos to go through the same process without worrying about memory. Optimized functions can lead to real-time processing for live video streams. As for users, the custom algorithms can be easily integrated. A popular open-source computer vision library is called OpenCV. systems that detect driver drowsiness.

2.2 Dlib

A range of machine-learning methods are included in the contemporary C toolkit Dlib and materials for creating complex C++ answers to real-world problems. Its versatility extends across numerous industries, including mobile devices, embedded systems, robotics, and large-scale high-performance computing settings.[7] In environments, with open-source licenses, Dlib has unconfined usage making it a popular environment for diverse applications. The author uses Dlib's CNN implementation where he incorporates very precisely tuned prediction inputs and outputs and sensors to identify face contour from the recognized face formations.

2.3 Eye Aspect Ratio

The numerator of the equation covers the vertical distance between some of the eye features while the denominator estimates the planar distance between reference points, its scale normalization taking into consideration their singularity. EAR measures the ratio of the eye opening's length to the distance between the eyes. The EAR value decreases as tiredness comes in because the eyelids droop [9]. The aspect ratio of the eye stays mostly constant when it is open, but it drastically drops to zero when it blinks**.**

$$\mathrm{EAR} = \frac{\|p_2 - p_6\| + \|p_3 - p_5\|}{2\|p_1 - p_4\|}$$

Fig. 2. Eye Aspect Ratio Formula

figure 2, The image illustrates the eye-aspect ratio (EAR) Formula, a measure used to determine the openness of the eyes. The EAR calculation formula is given, demonstrating how it is calculated using the separations between particular facial landmarks surrounding the eyes.

2.4 Mouth Aspect Ratio

The numerator of the equation expresses the distance of specific lips in the vertical axis while the denominator gives an estimated planar distance between two referent points; scale normalization considers the peculiarities of these landmarks. When the lips are in the state of repose the ratio does not differ considerably from the value calculated from the measure calculated on the masks, however, when a lip movement occurs for instance when the lips are pursed or relaxed, changes in the aspect ratio can be observed.

$$\mathrm{MAR} = \frac{|EF|}{|AB|}$$

Figure: Mouth Aspect Ratio Formula

Fig. 3. Mouth Aspect Ratio Formula

Fig. 3 demonstrates abrupt variations to represent an obstruction due to major lip movements and is used to identify drowsiness events when the lip movement pattern rapidly changes

2.5 Head Tilt Detection

The Head Tilt Detection module determines the degree to which the driver has tilted his head in order to detect signs of fatigue. It works depending on the orientation of the head with the help of facial landmarks and the position of the eyes, nose, and ears. To measure the degree of head tilt it is necessary to find out the angle between the vertical axis and the line determined by the eyes and the center of the nose.

2.6 Alert and Communication

The system also includes an alarm that goes off when a user has his eyes closed for more than 10 seconds, along with a notification system to send alerts after repeated alarms. This also provides sound playback to prompt the user in case sleepiness is detected for a certain duration. With Twilio integration, it sends SMS and calls with location details to make sure timely assistance is provided. It also informs family members about the user's state for added safety and, if necessary, rapid response to a critical situation.

3 Methodology

- **Data Acquisition**: The real-time, continuous recording of raw video feed from the smartphone camera forms our primary data source. Drowsy driving accounts for 20–25% of motor vehicle crashes, highlighting the need for real-time detection systems [5]. The acquired data undergoes continuous surveillance to identify vigilant and fatigue-prone activities.

- **Facial expression detection**: These lightweight, resource-efficient tools enable real-time, offline fatigue detection, making them practical for real-world applications. While advanced models like Vision Transformers and hybrid CNN-RNNs offer higher accuracy, the chosen approach prioritizes ease of integration and efficiency. Driver fatigue is a significant contributor to road accidents worldwide, and timely detection systems are crucial for enhancing driving safety and reducing casualties [6]. Preprocessing techniques such as Haar-cascade face detection and VGG-Face models are commonly used for facial feature extraction in fatigue detection systems, improving detection efficiency and accuracy [7].

- **Alert Generation**: The first thing to do is to alert the user when the system detects drowsiness. We will activate a local alarm that makes it clear to the user that they are falling asleep. If the alert is triggered, however after about 10 seconds of rest and it detects drowsy eyes then the alarm will be boosted. If this condition is further triggered after 15 seconds, then a louder alarm will sound. If the alert does not stop for 30 seconds.

- **Report Generation**: Finally, our system will generate a report at the end of each session of time. The report will be used to estimate the fatigue of the user over time.

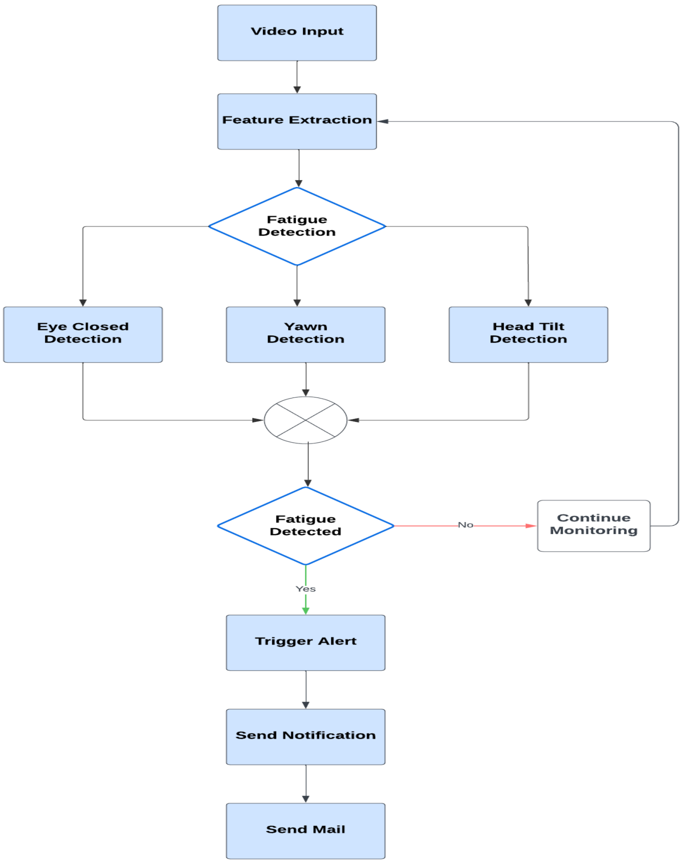

Fig. 4. Workflow of fatigue monitoring system

The workflow describes a real-time fatigue monitoring system that incorporates facial expression recognition and alert mechanisms. Using facial landmark detection, it processes live video input to detect drowsiness indicators like prolonged eye closure, head tilts, and lip movements. If no fatigue is detected, the system continues real-time monitoring. Thus, it detects fatigue-like signs- for example, by triggering a local sound alarm, closing the eyes for more than 10 seconds- or frequent drowsy patterns. When consistently noticing this drowsiness, after some time, it issues notifications to family members using Twilio through SMS or by actually calling. It logs detailed information about the session on a report.

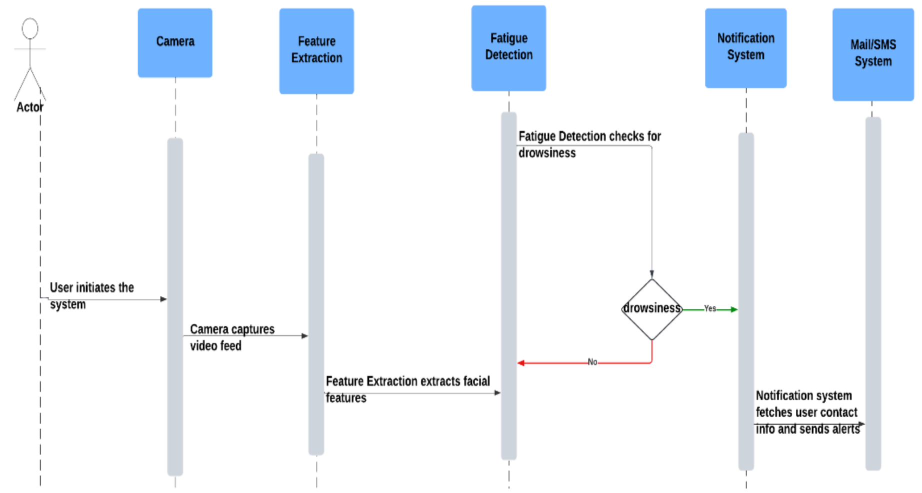

Fig. 5. Fatigue Monitoring System Sequence Diagram.

Real-time Driver Drowsiness Detection: The system monitors driver fatigue by analyzing video input of the driver's face and eyes. Feature extraction detects signs such as prolonged eye closure or reduced blink rates. Continuous monitoring is done in the case of nondetection of drowsiness. Upon the detection of fatigue, it will send an alert to the driver or the contacts identified through email or SMS, thus motivating timely intervention for enhancement in the safety aspect.

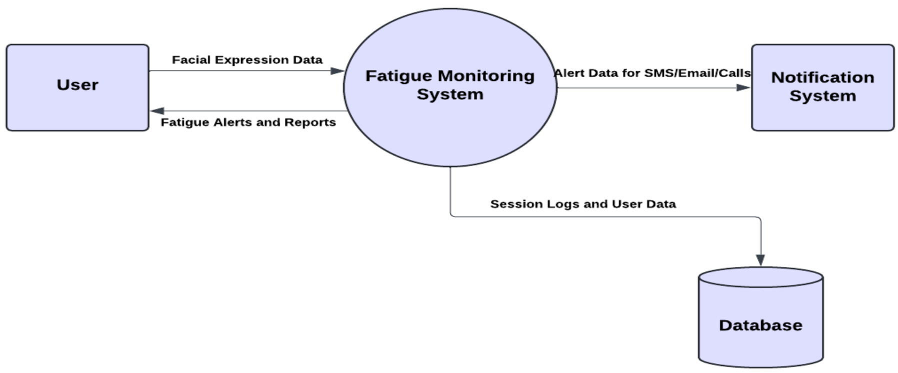

Fig. 6. Fatigue Monitoring System DFD.

This is your Real-Time Fatigue Monitoring System’s Level 0 Data Flow Diagram (DFD). The data flow between the core system, external entities, and various components is depicted in the diagram. The system consists of four major components interacting and working with each other: from the user interface, the system captures facial expression data, including eye closure and lip movement; This abrupt change signal a blink event as the aspect ratio swiftly declines and subsequently rebounds [8]. As drowsiness sets in, the eyelids droop, causing a decrease in the EAR value [9]. It also receives fatigue alerts and reports based on system analysis. The Fatigue Monitoring System processes facial data, detects drowsiness, generates alerts, and creates session reports. It will also update the database at the end of each session with user data and logs. The Notification System takes the alert data and sends notifications to the user or the recipients via SMS, email, or calls.

4 Literature Review

Fatigue, or the state of physical and mental exhaustion, is a serious threat to safety and productivity in many areas, such as driving and industrial work. Current methods of fatigue assessment, such as questionnaires or body measurements, are quite accurate but cannot be applied in real-time. Several studies have pointed out the use of HRV signal features for the detection of fatigue with high accuracy as high as 94.8%. Recent breakthroughs in computer vision include the Vision Transformers, hybrid CNN-RNN models, and YOLO; all these have greatly enhanced real-time fatigue detection by incorporating both spatial and temporal feature analysis. These techniques further offer even higher accuracy and responsiveness but at the cost of large computational resources.

Table 1. Comparison table for papers

Paper Title	Objective	Methodology	Results
Facial Detection for Recognition of Drowsiness [2024]	Facial detection system for drowsiness recognition.	embedded with computer vision to detect drowsiness from the face	Accurate real-time sleepiness detection would be possible.
Advancements and Perspectives in Fatigue Driving Detection: A Comprehensive Review [2024]	Review of advancements in fatigue detection for drivers.	Recent Work on Driver Fatigue Detection Different technologies implemented for driver fatigue detection	This paper summarises the progress in current technologies and identifies the gaps, as well as ideas for future research on fatigue detection technologies.
Driver Drowsiness Detection System [2024]	A face feature-based approach for detecting drowsiness.	real-time drowsiness detection, using the Dlib was combined	Machine learning-based webcam-based precise detection and warning system.

Driver Drowsiness Detection Using CNN and Real-Time Monitoring [2023]	Drowsy detection using the camera by eye-blinking rates and eyeball sizes.	Determine using CNN using a webcam in real-time.	Because it was based on eye movement-related drowsy driving, it has achieved a high detection rate a
Alert System for Driver Drowsiness Using Real-Time Detection [2020]	To develop a system for the real-time detection of driver drowsiness.	Python, OpenCV, and a webcam to track eye and lip movement if drowsy, it sounds an alert.	It successfully detected drowsiness based on the time that a person kept his or her eyes closed and issued sound warnings.

5 Result Analysis: Event Timeline

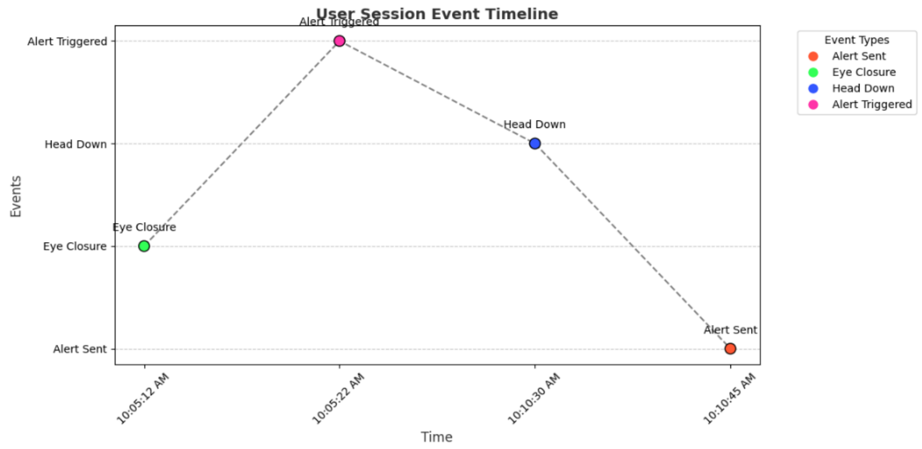

Fig. 7. User Session Event Timeline

The graph depicts the sequence of key events in the user session.

- At 10:05:12 AM, it detected Eye Closure for a duration of 10 seconds. At 10:05:22 AM, an alert-triggered event was recorded wherein the system had to play an alarm.
- Head Down detection at 10:10:30 AM for 15 seconds; this could be a potential indication of fatigue
- An Alert Sent event at 10:10:45 AM indicates that the system started sending an SMS and call to the user.

Each event will be represented by a different color that corresponds to its type, to facilitate the identification of them. Thus, the timeline will give the sequence of system responses to the signs of drowsiness, from detecting an alert.

6 Conclusion

To identify drowsiness in real time, the Real-Time Fatigue Monitoring System successfully integrates head movement, yawn detection, blink rate analysis A threshold value of drowsy eye blink sample represents the number of video frames of the driver’s closed eyes [10], and face landmark detection. In sum, the ability of the system to intervene through an alarm and Twilio-powered notification ensures timely responses against signs of inattentiveness, which makes it very effective in preventing fatigue-related incidents. Second, session reporting also gives the developers some insight into the patterns of fatigue that might be used to improve user safety and fine-tune the system even further. The current implementation is pretty robust on daily fatigue detection, though there indeed is room for improvement. This could enable subtle detection, refining the design of alerts for user experience by possibly integrating the system with machine learning models and physiological signals. Further verticals could be the inclusion of driver safety, workplaces, and healthcare, making the system more worthy of creation to create an indelible mark in varied disciplines concerned with safety and well-being

7 Future Scope

The next generation of fatigue detection systems could offer a better alternative for current limitations and applications. When a level of drowsiness is detected, the motor will slow down and the engine stops functioning [11]. It would be even more profound to integrate multi-modalities, like biometric data from wearables, including heart rate and SpO2 with face analytics for deeper insights into adaptive fatigue thresholds based on the user's behavior. Recently developed technologies such as Vision Transformers and hybrid CNN-RNN model hypersensitive personalized monitoring by learning the user-specific pattern. OpenCV was intended for picture handling. Each capacity and information structure has been planned given an Image Processing application [12].

Infrared or thermal cameras can overcome the challenges presented by low-light environments, and infrared or thermal cameras overcome low-light environment challenges; smart wearables and sensor real-time data integration will drive dynamic fatigue detection. Applications also involve workplace safety, healthcare, and transportation, in which monitoring fatigue could avert expensive mistakes. These are the avenues to holistic frameworks of fatigue analysis informed by empirical evidence, refining future system designs.

8 References

1. IoT with Firebase: Android Smart Ring App for Fatigue Detection Using MAX30100. (2024). Journal of Information, Communication, Electronic, and Electrical Technology (JEEICT).
2. Facial Detection for Recognition of Drowsiness. (2024). University of Kasdi Merbah Ouargla.
3. A Deep Neural Network Hybrid Method for Identifying Driver Fatigue. (2024). Journal of Intelligent Systems, Wiley International.
4. Driver Fatigue Detection Using Cognitive and Biometric Monitoring. (2023). PLOS ONE.
5. Driver Fatigue Detection Using Heart Rate Variability Features from ECG Signals While Accounting for Sex Differences. (2024). MDPI: Sensors.
6. Advancements and Perspectives in Fatigue Driving Detection: A Comprehensive Review. (2024).
7. DA-ViViT: Fatigue Detection Framework Using Joint and Facial Key Point Features with Dynamic Distributed Attention Video Vision Transformer. (2024).
8. System for Detecting Driver Drowsiness. (2024). Journal of Science and Research Archive International.
9. Driver Drowsiness Detection Using CNN and Real-Time Monitoring. (2023). Journal of Data Acquisition and Processing.
10. Smart Alert System Based on IoT for Identifying Sleepy Drivers. (2021). Journal of Mobile Computing and Wireless Communications, Hindawi.
11. Driver monitoring with a real-time drowsiness detection system. (2020). Materials Science and Engineering Conference Series, IOP.
12. Real-time detection alert system for driver drowsiness. (2020) Engineering Research and Technology International Journal (IJERT)